STATINTL [redacted], INC.

READING FILM WITH A COMPUTER

A computer system has been developed for reading scientific data recorded on 16 or 35 mm. film. The film reading system is based on three major elements: a PDP-1 digital computer, together with a visual display scope; a film reading device; and computer programs for using the computer and film reader.

The film reading process involves the scanning of film by a rapidly moving light point on the visual display scope. The output of this scanning operation is detected by a photo-sensitive device in the film reader and relayed to the digital computer for further processing and analysis. Various types of data output are available.

Using 16 or 35 mm. film as a medium for recording scientific data has many advantages. Because of the small input power and limited storage space that are required, it is particularly suitable for recording data produced by recording devices in space vehicles or aircraft; by wind and current measuring devices, and by other devices of similar nature.

However, reading or transcribing the data from film once it has been recorded has presented many problems in the past. It has generally been necessary for an analyst or researcher to read the data visually from the film and transcribe it by hand. This has been found to be a time-consuming, laborious and relatively expensive operation.

STATINTL [redacted] has now developed a film reading system which can read data from film automatically and list (print out) the data on paper or record it on magnetic tape for further computer processing and analysis. The film reading system is based on three major elements: a PDP-1

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digital computer, together with a visual display scope; a film reading device; and computer programs for using the computer and film reader.

The film reading process involves the scanning of film by a rapidly moving light point on the visual display scope. The output of this scanning operation is detected by a photo-sensitive device in the film reader and relayed to the digital computer for further processing and analysis. In addition to translating the data itself into a more desirable format, the film reading system can also furnish additional summaries and analyses of the data as may be required.

The flexibility of the film reading system in two respects should be emphasized. First, almost any format of data on film can be read, with appropriate modifications to the basic computer program. This includes data represented in the form of lines, graphs (e.g., radar pulses), points, and other similar forms of data. Second, almost any type of desired output may be obtained once the basic data is obtained from the film. Forms of output which are available include the following:

(i) A print-out or listing of data on paper.

(ii) A record of the data on magnetic tape.

(iii) Visual representations of data. These may take the form of a continuous graph (using a digital x-y plotting device). Or they may take the form of photographs -- still or motion -- of scope displays. This latter format is particularly

flexible in that computer programs may be designed and written to provide many types of useful and informative data representations.

In addition to data recorded on film, data recorded on any light-permeable medium (such as light or medium weight paper) can also be read by means of the film reading system.

Applications of the film reading system include the following:

(i) Analysis of data produced by oscillographs or other types of graphic recorders

(ii) Tracking and analysis of objects for which motion pictures are available (e.g., missile tracking studies)

(iii) Reading of astronomical or astrophysical data recorded on film (e.g., analysis of stellar configurations)

(iv) Reading photographs of cloud chambers, bubble chambers, and spark chambers.

(v) Counting of particles (such as blood cells or bacteria) in photographs.

Case Example: Missile tracking studies

STAT INTL [redacted] has recently completed the development of a film reading system to read data representing missile tracking studies recorded in the form of radar pulses on 35 mm. film. A film reading system was developed with the following

capabilities:

(i) Approximately 500 readings per frame of the amplitude of the radar signals

(ii) Computation of the median amplitude value for each frame

(iii) Count of the number of radar pulses

(iv) For each radar pulse, a measurement of pulse width, average amplitude during the pulse, and measurement of the location of the leading edge of the pulse

(v) Recording on magnetic tape of all original and processed data.

Case Example: Oceanographic current meter film

STAT [redacted] has also developed a similar system to read data recorded on film by oceanographic current meters. These current meters are located in specific oceanic areas. They contain devices for automatically recording information, such as the direction and rate of flow of ocean currents, on film. Data is recorded in the form of interrupted lines or bars on 16 mm. film. The film reading system can collect and analyze this data, and produce output of both original and processed data onto paper or magnetic tape.

PROGRAMMABLE FILM READER

(PFR-1)

Technical Specifications and Price List

1. General.

The Programmable Film Reader, PFR-1, has been designed to read large quantities of data from photographic films.

These films may be produced by many different instruments; thus, their formats may differ widely. The Programmable Film Reader can be adapted to these various formats and conditions by use of appropriate programs.

In general, the Programmable Film Reader, after it is adjusted and programmed, can, under average circumstances, read points automatically at a rate of approximately 5000 points a second. Thus it has a very great factor of advantage over prior methods of reading film which make use of a human being to look at recordings on film, and position a reading instruments.

In addition, the Programmable Film Reader is very sensitive to changes of the photographic density of film, and it can employ extremely complex logic in order to read while disregarding film "noise". It can often read recordings which are beyond the capacity of a human being to read. The scanning technique employed is a significant improvement over conventional "flying spot" scanning techniques. Instead of scanning and storing data for every point in the display raster, the scanning technique developed for the

(c)

Programmable Film Reader is based on locating and tracking only the data of interest on the film. Since only these points are stored and processed, this technique results in considerable savings in required storage space and film reading time.

The principle of operation of the film reader is as follows:

(1) a source of light consisting of a bright spot is produced at a specified location on the face of the cathode ray tube of the display unit of the computer;

(2) light coming from this spot is divided into two beams.

One beam:

(3) passes through a lens, and is focused on the film to be read, on a corresponding specified location;

(4) the light transmitted through the film at this location goes through a collector lens, is defocussed, and

(5) is sensed on the cathode of a photomultiplier tube;

(6) the signal is amplified and its voltage measured;

The other beam, for comparison purposes:

(7) passes through a second lens along a different path, which does not include the film being read;

(8) is sensed on the cathode of a second photomultiplier; and

(9) the signal is amplified and its voltage measured.

The two signals are passed through a difference amplifier; in this way a comparison is made, and the output is processed in accordance

with wired-in logic circuits in the equipment (the Signal Processor and Logic Unit), under the direction of an appropriate program.

Specifically, the Signal Processor and Logic Unit (SPLU), under control of the Scan Control and Monitoring Unit (SCMU), determines if the density of the image on the film at a selected spot, at the time of peak illumination, is greater or less than a given value. If so, an appropriate signal is sent to the Scan Control and Monitoring Unit (SCMU). This signal is interpreted by the program, and the digitized results can be stored on IBM format magnetic tape.

Density measurement is made by comparison with a density standard. This standard is the sum of the equivalent density of beam splitter ratio, lens aperture settings, and neutral density filters. The normal system response is a one-bit decision, i.e., the film is classified as more or less dense than the standard. By means of intensity control of the programmable light source, such measurement is possible with film densities ranging from 0.0 to 2.0. If the density difference between the density standard and the film is 0.2 or greater, then a reliable signal will be produced. For example, if the density standard is 1.70, then measurement at any point on the film which yields a measurement equal to or greater than 1.90 will result in a "more dense" decision.

The Programmable Film Reader System (Type PFR-1) is composed of:

(1) The Basic Film Reader, Type 1000. This in turn is composed of:
   (a) The Optical and Mechanical Unit (OMU).
   (b) The Signal Processor and Logic Unit (SPLU).
(2) The Film Transport and Objective Lens Unit (Type 1020 or 1021 or 1022)
(3) The Precision Programmable Light Source (Type 2000)
(4) The Scan Control and Monitoring Unit (SCMU) and its auxiliary equipment (Type 3000, 3020 and 3022)

2. Optical and Mechanical Unit.

The OMU contains the mechanisms which unwind and rewind film; control the focus, image size (magnification), and inclination of the film; contain the photomultipliers and their associated circuitry; etc.

2.1 Film Handling.

The Film Transport and Objective Lens Unit is placed in the OMU. It contains appropriate lenses, beam splitter, etc., adapted to the customer's selection of size of film to be read: 35 mm (Type 1020), 16 mm (Type 1021), or 70 mm (Type 1022). This unit also contains a mechanism which sets the amount of advance of the film. The amount of the advance can be specified within reasonable limits when ordering the Film Transport and Objective Lens Unit. Many other amounts of advance besides the standard

amounts of advance are available.

The OMU reads film, either framed or continuously exposed, with sprocket holes. (Reels are provided for film length up to 1000 feet.) Film is automatically advanced under control of the Scan Control and Monitoring Unit. The film advance requires less than 0.1 seconds and normally consists of 2 sprocket holes for 35 mm or 70 mm film, and 1 sprocket hole for 16 mm film.

In cases where more than one type of Film Transport and Objective Lens Unit is purchased, the OMU can be converted from accepting one film size to accepting another (for example, from 16 mm to 35 mm) in less than half an hour.

2.2 Field of View.

The film reader has a field of view large enough so that no data need be lost, for instance, if the film is exposed without frames, or if data extends slightly into the sprocket hole area. Sufficient area at the sprocket hole region is visible to allow the program to precisely locate the sprocket holes.

2.3 Controls.

The OMU contains adjustment devices and indicators for controlling:

(a) focusing of the image;

(b) size of the image;

(c) orientation angle of the film being viewed, within a range of plus or minus ten degrees from the horizontal;

(d) operating conditions such as: high voltage too high or too low; photomultipliers clipping; too much ambient light within the film reader dark chamber; and other similar conditions (see Exhibit I).

(e) The motion of the film: forward or reverse, fast or slow, continuous stepping or single stepping.

3. Signal Processor and Logic Unit (SPLU).

The SPLU accepts input from the OMU, measures density, and makes the decision of "denser" or "less dense" than a given comparison standard.

3.1 Protection Circuits.

The SPLU protects the photomultiplier and other circuits in the OMU by means of circuits disconnecting the high voltage if certain limits of current or voltage are exceeded. Also, if the ambient light in the OMU cabinet as measured by a photoresistor exceeds a certain limit, the high voltage is disconnected.

3.2 Film Motion.

Film advance is controlled by the program. Resulting signals pass through the SPLU.

3.3 Equipment Signals.

The SPLU provides to the Scan Control and Monitoring Unit a number of indications of the status of equipment. Control over these indications is provided by switches and knobs on the OMU and the SPLU. The Scan Control and Monitoring Unit does not itself exercise any control, but furnishes typed information to the operator.

Exhibit I

PROGRAMMABLE FILM READER (PFR-1)

OPERATING CONDITIONS MONITORED AUTOMATICALLY BY THE FILM READING SYSTEM

Bit No.	Variable	Meaning of 0	Meaning of 1
1-0	Film advance flip-flop	not set	set
1-1	Film advance delay	advance complete	advance not complete
1-2	Photomultiplier warning status	safe	warning
1-3	Program switch A	not set	set
1-4	Program switch B	not set	set
1-5	Program switch C	not set	set
1-6	High voltage interrupt overide switch	high voltage on, only when safe	high voltage on, safe or not
1-7	High voltage relay	closed	open
1-8	Film polarity	positive, not normal	negative, normal
1-9	Advance film on program flag 6	cannot	can
1-10	Cathode ray tube coordinates	rotated 90°	normal
1-11	Film reel	neither reel empty	at least one ree empty
1-12	Photomultiplier 1 (which reads film)	signal OK	signal too stro tube clipping
1-13	Photomultiplier 2(which provides comparison)	signal OK	signal too stro tube clipping
1-14	Projection lamp	off	on
1-15	Circuit test switch	off	on
1-16	Film reel torque motors	off	on

One bit of information is provided for each indication (see Exhibit I).

These signals are presented in the In-Out Register of the Scan Control and Monitoring Unit, when called for by program instruction.

The Photomultiplier Warning status bit (bit 1-2 above) is the logical "or" of the following status indications:

Bit No.	Variable	Meaning of 0	Meaning of 1
2-0	High Voltage	not too high	too high
2-1	High Voltage	not too low	too low
2-2	Photomultiplier 1, anode current	OK	too high
2-3	Photomultiplier 2, anode current	OK	too high
2-4	Ambient light warning	OK (dark)	unwanted light entering the film reader housing

In all cases where damage to the photomultipliers might occur, the high voltage is automatically disconnected, except when the high voltage interrupt overide switch in the OMU is on.

These signals are presented in the In-Out Register of the Scan Control and Monitoring Unit when called for by program instruction.

4. Precision Programmable CRT Light Source, Type 2000.

The Programmable Film Reader attaches to the Type 2000

Precision Programmable CRT Light Source.

4.1 Speed of Operation.

Upon designation by the Scan Control and Monitoring Unit of a specific X,Y coordinate pair, or sequence of selected pairs, the CRT illuminates each given spot in not more than 50 microseconds.

A succession of arbitrary points on the film may be interrogated as often as one every 50 microseconds.

4.2 Other Operating Specifications.

(a) Raster size: 9 and 3/8 inches by 9 and 3/8 inches containing 1024 points by 1024 points.

(b) Pin cushion distortion: less than 3/16 inch per side

(c) Magnetic deflection and magnetic focus.

(d) Spot size: approximately 0.030 inch; 0.015 inch at the half-power points.

(e) Deflection sensitivity: 0.009 inch change for change of least significant digit in address

(f) Addressing scheme: 1's complement, with plus zero equal to minus zero at the center of the screen for each axis. May be adjusted for 2's complement.

(g) Stability of origin and of deflection system: plus or minus 0.5 percent of raster size.

(h) Accuracy: plus or minus 3% of raster size overall

(i) Repeatability: plus or minus 0.05 inch, regardless of the location of the preceding point.

(j) Timing sequence: 2.5 microseconds for address transfer, 35 microseconds for deflection setup, and 10 microseconds for spot intensification

(k) Intensification: 8 levels of intensity, controlled by the computer

(l) Indicators: Current state of the coordinate address is shown on two rows of ten lights. A row of four lights indicates the status of the Light Pen and intensification circuits.

(m) Coordinate change: The normal X-Y coordinate system of the display may be switched to a position where the X-Y coordinates are rotated 90° in a counter clockwise direction, so that the positive X-axis instead of being vertically upqard is horizontally to the left.

5. Scan Control and Monitoring Unit.

The Type 3000 Scan Control and Monitoring Unit is a high speed solid state digital device designed to operate the film reading system under the guidance of an appropriate program. Program features include: single address instructions, multiple step indirect addressing and logical arithmetic commands. The word length is 18 binary digits. Instructions are performed in multiples of the memory cycle time of five microseconds. Add, subtract, deposit, and load, for examples, are two-cycle instructions requiring 10

microseconds. Console features include: flip-flop indicators grouped for convenient octal reading, six program flags for automatic setting and sensing by the SCMU, and six sense switches for manual setting and sensing by the SCMU.

The Scan Control and Monitoring Unit accepts information through input registers; controls the positioning of the light point; and through output registers controls the scanning actions and the film advance. Successive density readings may be taken every 50 microseconds. The magnetic core memory of the Scan Control and Monitoring Unit holds 4096 words of 18 bits each. It may be expanded, in increments of 4096 words, to a maximum of 65,536 words.

Auxiliary equipment includes a magnetic tape transport (Type 3022) and a magnetic tape control (Type 3020). The magnetic tape is compatible with IBM tape formats (load point, lateral parity, longitudinal parity, record gap, end of file mark, etc.). Recording density is 200 seven-bit characters per inch.

6. Local Contrast Measurement Option.

Local contrast measurement circuitry is available as an option. This enables the comparison of the density of a specific point on the film with the density of a surrounding area (a disc with the specific point as center) on the film.

In operation, when a display command is given, a defocus pulse is applied to the focus modulator driver located in the Programmable Light Source. This causes current in the dynamic winding of the

focus coil to increase, which in turn causes the light point to be defocused. At the end of the defocus command the current in the focus coil decreases at the same rate and ultimately refocuses into a point. The integrated signal produced over the defocused area is compared with the signal at the focused point source. The difference detection circuit has a three-state output: "equal", "greater than", or "less than". If the unfocussed spot and focussed spot are in a field of uniform density, the signal from the film and the integrated signal are equal in amplitude within an adjusted threshold, an "equal to" indication is given. If an area of greater density, such as a line, intersects the unfocussed spot, a "greater than" (point bright) indication is given. If the line intersected the focussed spot, a "less than" (point dim) indication would be given. In this way, it is possible to detect areas of increasing (or decreasing) density on the film.

7. Cabinets.

The OMU and the SPLU are housed in attractive cabinet racks. The OMU includes a solid platform or table.

7.1 Power: The system operates from a power source of 117 volts a-c, 60 cycles, single phase power and gives specified performance for voltage from 105 to 125 volts.

7.2 Dust, Vibration, etc. The equipment should be operated in an environment with low dust, and little vibration. The room lighting should be by incandescent lamps rather than by fluorescent lamps.

PRICE LIST

A complete Programmable Film Reader System, Type PFR-1, consists of the following units:

Type	Name
4000	Basic Film Reader
1020 or 1021 or 1022	Film Transport and Objective Lens Unit
1040	Local Contrast Signal Processing Option
3020	Magnetic Tape Control
3022	Magnetic Tape Transport
2020	Light Pen

25X1A

Each of these is briefly identified and described below:

A. Basic Film Reader, Type 4000 consisting of:

1. Optical and Mechanical Unit (OMU), Type 1001
2. Signal Processor and Logic Unit (SPLU), Type 1002 with precision density threshold
3. Scan Control and Monitoring Unit (SCMU), Type 3000 with 4096 word core memory
4. Precision Programmable CRT Light Source, Type 2000

B. Film Transport and Objective Lens Units, with appropriate lenses, beam splitters, etc:

Type 1020, for 35 millimeter film

Type 1021, for 16 millimeter film

Type 1022, for 70 millimeter film

C. Signal Processing Option

Type 1040, Local Contrast Compairson Circuits and Logic

D. Magnetic Tape Control, Type 3020, and Tape Transport, Type 3022

E. Light Pen, Type 2020

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Example

Complete Programmable Film Reader System, Type PFR-1, for 35 millimeter film:

Consisting of Units:

Type	Description
4000	Basic Film Reader
1020	Film Transport (35 mm film)
1040	Signal Processing Option
3020 & 3022	Magnetic Tape Control and Transport
2020	Light Pen
	TOTAL

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Remarks:

Herewith is a copy of my file material on the Computer-Controlled Film Reader now being developed by STATINTL

I also include a copy of the Contact Division report of my visit on 31 July 64.

I am interested to keep in touch further on this especially on the computer control and programming aspects.

(a)

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